AD-A133390

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US ARMY TEST AND EVALUATION COMMAND
INTERNATIONAL TEST OPERATIONS PROCEDURE

*International Test Operations Procedure 4-2-812 1 November 1983
AD No. A133390

PENETRATION TESTS OF HEAT WARHEADS

Page

APPLICABILITY. This document has been approved for joint usage by the US and Germany.

1. SCOPE. This TOP describes procedures for determining the penetration ability of high explosive antitank (HEAT) warheads during development and acceptance tests of antitank projectiles, missiles, and rockets. Included are static tests that determine penetration as a function of standoff distance and spin rate, and dynamic tests that provide data on armor penetration at various obliquities and standoff distances. Basic features of a typical HEAT warhead are described in Appendix A.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENT
Test sites	Areas for static and dynamic testing that provide for safety of test personnel with regard to shelters and minimum distances to target and behind launchers

*This ITOP supersedes TOP 4-2-812 dated 6 October 1980.

Encl 1

ITEM (cont'd)	REQUIREMENT (cont'd)
Target	Armor plate (e.g., rolled homogenous), thickness depending on type of HEAT warhead, its penetration capabilities, etc.
Temperature chambers	To condition ammunition to 21° C ±1° (70° F ±2°), -45° C ±1° (-49° F ±2°), and 63° C ±1° (145° F ±2°) if not specified otherwise
Adapter plug or modified boom assembly	A plug or fuze fabricated to provide remote detonation of warhead (para 4.1a). For static spin tests, it must also provide a means of attaching the projectile to the suspension system
Firing device	To remotely detonate the warhead
Spin device (arbor and motor with a variable power supply)	To provide specified rates of spin
Protective enclosure	To support and protect the static spin test equipment from fragmentation
Suspension system	To stabilize the projectile vertically over the target during static spin tests and provide fuze wire connections (para 4.1.2a)

2.2 Instrumentation.

DEVICE FOR MEASURING	MAXIMUM PERMISSIBLE ERROR OF MEASUREMENT*
Spin rate (typically, photoelectric sensor, light source, and counter or rotor, magnetic pickup, and counter)	±0.5%
Radiographic	1% penetrometer sensitivity in 0.3-m (1-ft) steel
Brinell hardness	230 to 380 Bhn; ±0.05 mm (0.002 in.) of indentation reading
Projectile speed	
Armor plate thickness	±0.25 mm (0.01 in.)

*Values can be assumed to represent ± 2 SD; thus, the stated tolerances should not be exceeded in more than 1 measurement of 20.

3. REQUIRED TEST CONDITIONS.

3.1 Test Item. Inspect each test item for damage and defective or missing parts, using visual and nondestructive procedures (TOP 3-2-807[1*]). Test item configuration will dictate the method of inspection. Record a description of the test item and all defects and modifications, including the following:

a. Nomenclature, including model number
b. Manufacturer and manufacturer's lot number
c. Evidence of defective parts
d. Any missing parts
e. Evidence of voids or fissures within the explosive fill
f. Any discrepancies from applicable drawings
g. Length
h. Weight
i. Outside diameter(s)
j. Center of gravity
k. Weight and composition of explosive filler
l. Charge diameter
m. Cone diameter and alloy
n. Design (built-in) standoff
o. For fuzing system components:

(1) Location (nose or base)
(2) Operating characteristics

3.2 Test Planning.

a. Review all instructional materials (including system support packages) issued with the test item, and review reports of previous tests of similar items.

b. Review the Safety Assessment Report (SAR) provided by the developer to determine whether all hazards have been identified; write the test plan to include subtests suitable for evaluating them.

c. Select penetration tests applicable to the test item from paragraph 4.

d. Select applicable pre-test and post-test nondestructive inspection.

e. Prepare an operational checklist for the specific test item and situation.

f. Make sure pertinent Standing Operating Procedures (SOPs) and Test Operations Procedures (TOPs) are at the test site. Observe all applicable SOPs during testing.

g. Make sure all personnel involved in testing are thoroughly familiar with provisions of SOPs and are fully capable of implementing them before any testing is begun.

*Footnote numbers correspond to reference numbers in Appendix C.

3.3 Test Controls.

a. Test warheads under ambient temperatures (generally 4° to 35° C [39° to 95° F]), except when specific temperatures are required.

b. Modifications of the explosive train that are necessary to statically detonate the munitions must be accomplished so that the integrity and positioning of the explosive train and detonating device are maintained to simulate the original configuration. When testing munitions with unusual or unique detonating devices, personnel must thoroughly understand their function before modifying the test item.

4. TEST PROCEDURES.

4.1 Static Tests. These are usually customer tests to help a developer improve the design of a developmental item. Conduct static tests only to investigate the effect of changing certain parameters such as spin rate, standoff, configuration of shaped charge liner, changes in explosive filler, etc. Do not conduct static tests to obtain a true indication of projectile, rocket, or missile performance as when fired dynamically to impact a target. Prepare for static detonation tests as follows:

a. Test Item Preparation. Prepare the test item for remote detonation by modifying the test item to accommodate an electrically functioning detonator and installing the detonator, booster cap, and an appropriate adapter plug (fig. 1) in the test item, or by mounting an adapter plug containing an electric detonator in place of the base detonator, or by modifying the boom assembly to accommodate an electrically functioning detonator. This modified boom assembly more exactly duplicates the original projectile configuration and becomes a self-suspending system. It is imperative that the detonator and its location simulate that to be used with a service round, and it must provide enough energy to reliably initiate the warhead explosive. The test item may also be modified by modifying the boom assembly (if the warhead has one) to accommodate an electrically functioning detonator (fig. 2).

The preferred configuration of the warhead in static detonation tests is with the ogive and the point-initiating fuze element in place because they contribute to a reduction in penetrating ability. If the ogive and fuze are not available, as is sometimes the case in early developmental studies, the limitations of the data should be recognized.

b. Plate Preparation. Cut the armor plate (see note below) into squares of a size (never less than 20-cm [8-in.] square) that will adequately contain one or more penetrations. Mark each plate for identification. For each detonation, stack the squares of armor plate as required to completely contain the total penetration and in such a way as to eliminate the air space between the plates. Use thick armor plate of about the same hardness for each target arrangement.

NOTE: Mild steel may replace armor plate if the relationship between penetration into mild steel and into armor plate is known; however, mild steel is not a suitable target material if the hole profile is to be determined.

Penetration into a stack of thin armor plates may not be the same as into a stack of thick armor plates.

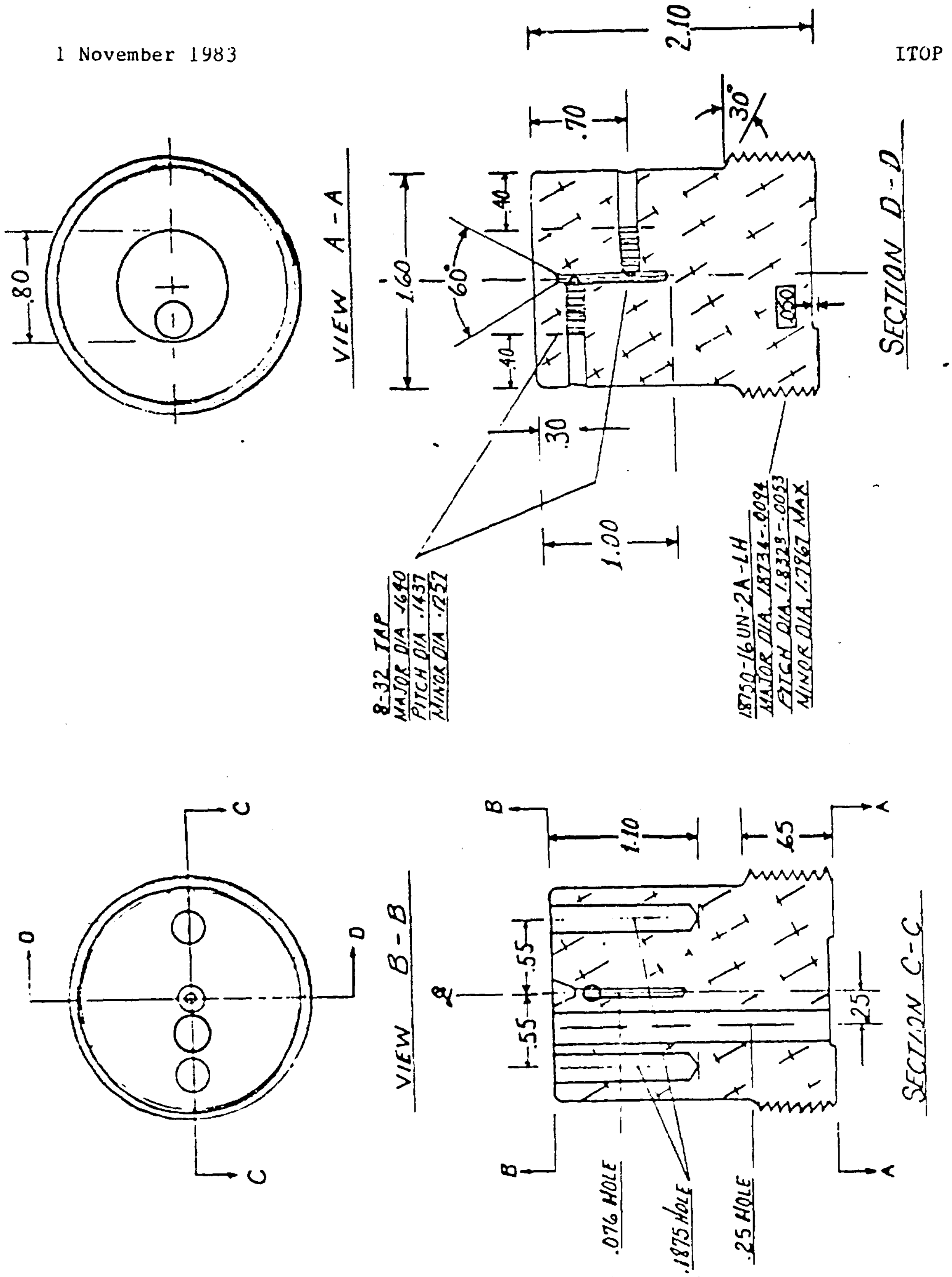

Figure 1. Example of aluminum adaptor for static tests with projectile, HEAT, 90-mm, M431.

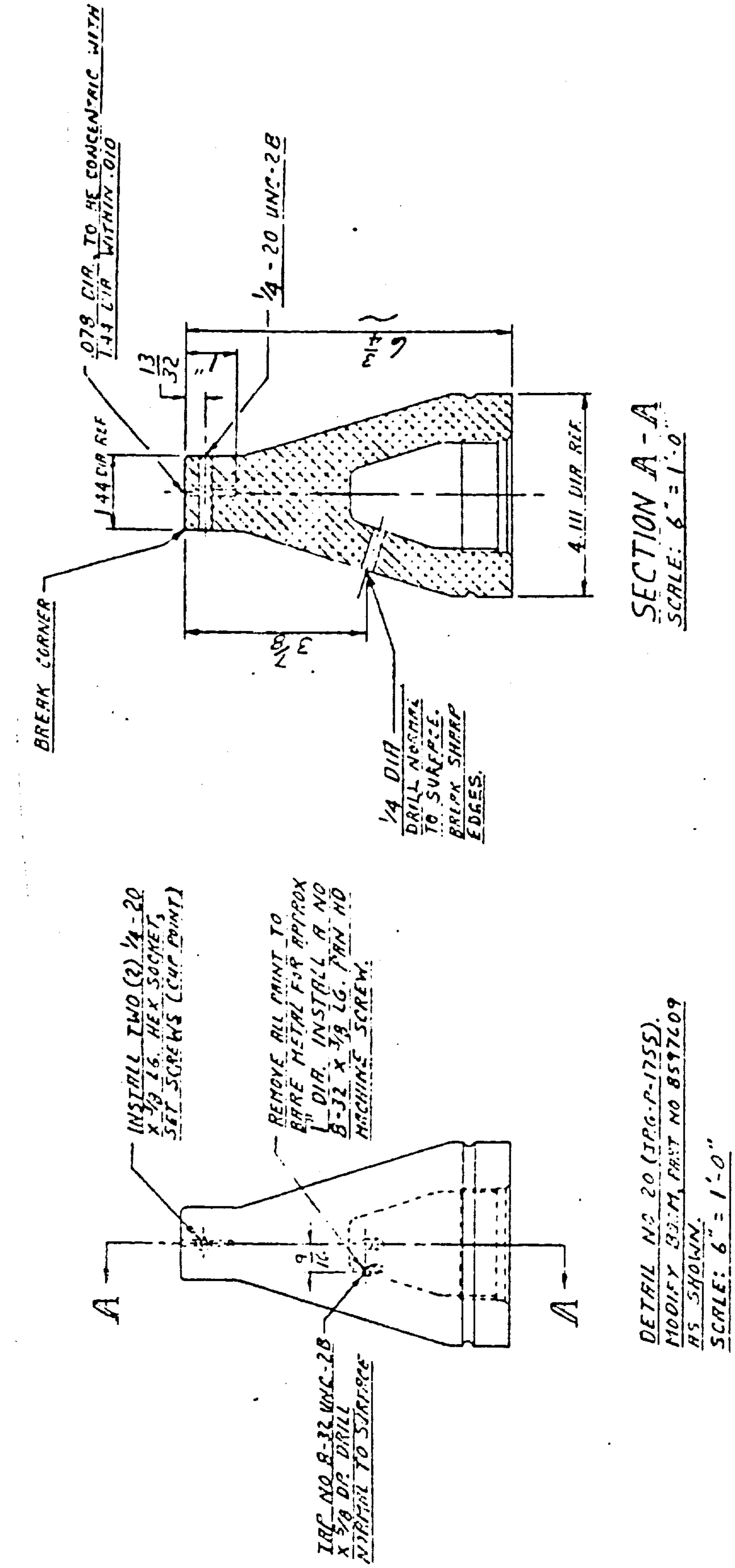

Figure 2. Example of modified boom assembly for fin-stabilized round for static tests.

c. Test Schedule. A typical schedule for conducting static tests is shown in Table 1. If mild temperatures are not prevalent, condition the test items to 21° C before testing.

d. Fair Hit Criteria. When the same plate is used for multiple tests, the fair hit criteria of Figure 6 must be applied.

TABLE 1
TYPICAL CONDITIONS FOR STATIC TESTS

Condition	No. of Rounds	Standoff Distance[a]	Target Obliquity
1	5	Design	Normal (0°)
2	5	4 charge diameters	Normal (0°)
3	5	8 charge diameters	Normal (0°)
4	5	12 charge diameters	Normal (0°)

[a]Standoff is the distance from the base of the liner to the target surface specified in warhead charge diameters (fig. A-1, Appendix A).

4.1.1 Static Nonspin Tests. Use the static nonspin test almost exclusively to determine penetration versus standoff.

a. Method. Mount the test item over the target armor plate at its design standoff distance, using wooden blocks or other suitable spacers, and then detonate by a remote firing device. Repeat the procedure to complete the conditions of Table 1 or as otherwise specified. When required, repeat the entire test with the same test items (except for the armor plate) conditioned to 63° C and -45° C, or as specified in the test directive.

For each detonation, measure the depth of the resultant jet penetration and, if required, determine the penetration hole profile (Appendix B).

b. Data Required. Record the following for each detonation:

(1) Test item temperature
(2) Total number of target plates and plate description
(3) Thickness of target plates
(4) Hardness of armor plates
(5) Test item standoff distance in charge diameters
(6) Penetration in centimeters
(7) Penetration hole profile and volume (when applicable)
(8) Ambient temperature
(9) Target angle
(10) Description of target setup

4.1.2 Static Spin Tests. Static spin tests are mainly used for determining penetration versus spin rate or, given a certain spin rate, to determine how design changes affect penetration.

a. Method. A typical test setup (see Figure 3) consists of a protective enclosure with a spin device, photoelectric sensor, and light source, installed

to provide and monitor warhead rotation. Locate a variable power supply, counter, and firing device remotely, and connect these to the spin device, photoelectric sensor, and fuze wire, respectively. Suspend the test item vertically, with the ogive of the projectile down, over the target armor plate at the required standoff distance by a suspension system (as shown in fig. 4-5), and then detonate while it is spinning about its longitudinal axis at the specified rate of spin. Depending on test objectives, repeat the test to determine plate penetration for various standoff distances (Table I) at a specified spin rate or for various spin rates at a specified standoff distance. When required, repeat some of the test, with the test items conditioned to 63° C and -45° C to determine the effects of temperature. Generally, five detonations are performed under each set of conditions.

For each detonation, measure the depth of the resultant jet penetration, and if required, determine the penetration hole profile (Appendix B).

b. Data Required. Record the following for each detonation:

(1) Test item temperature
(2) Total number of target plates and plate description
(3) Thickness of target plates
(4) Hardness of armor plate
(5) Test item standoff distance in charge diameters
(6) Spin rate, rps
(7) Penetration in centimeters
(8) Penetration hole profile (when applicable)
(9) Ambient temperature
(10) Target angle
(11) Description of target setup

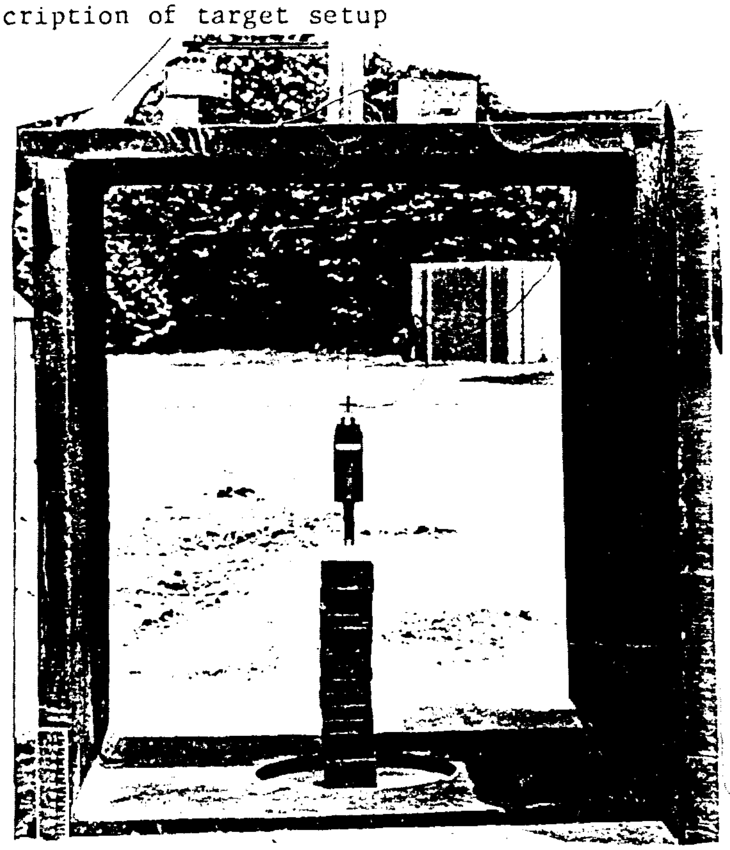

Figure 3. Example of typical test setup for static spin test.

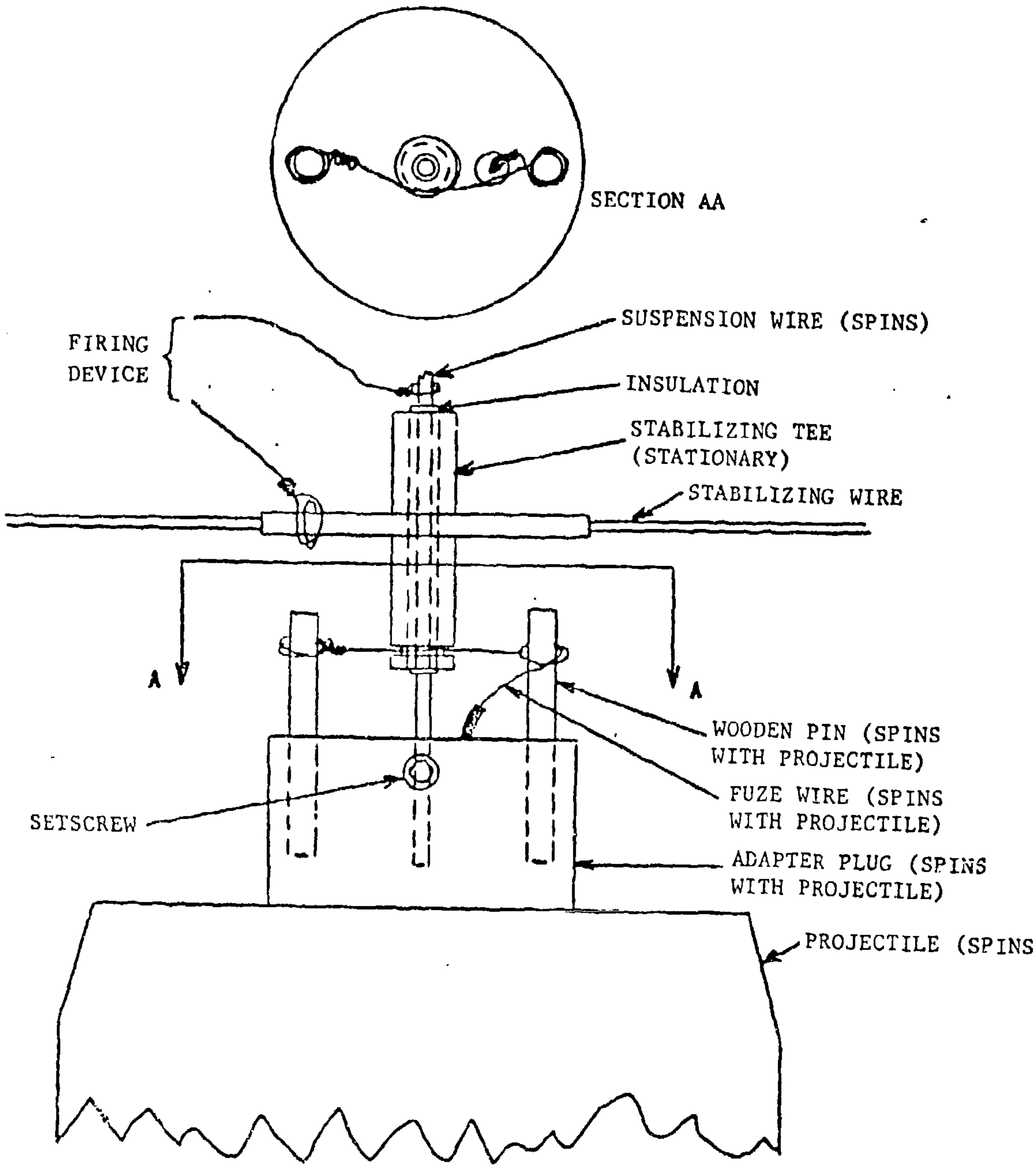

Figure 4. Example of system for suspending a spinning projectile.

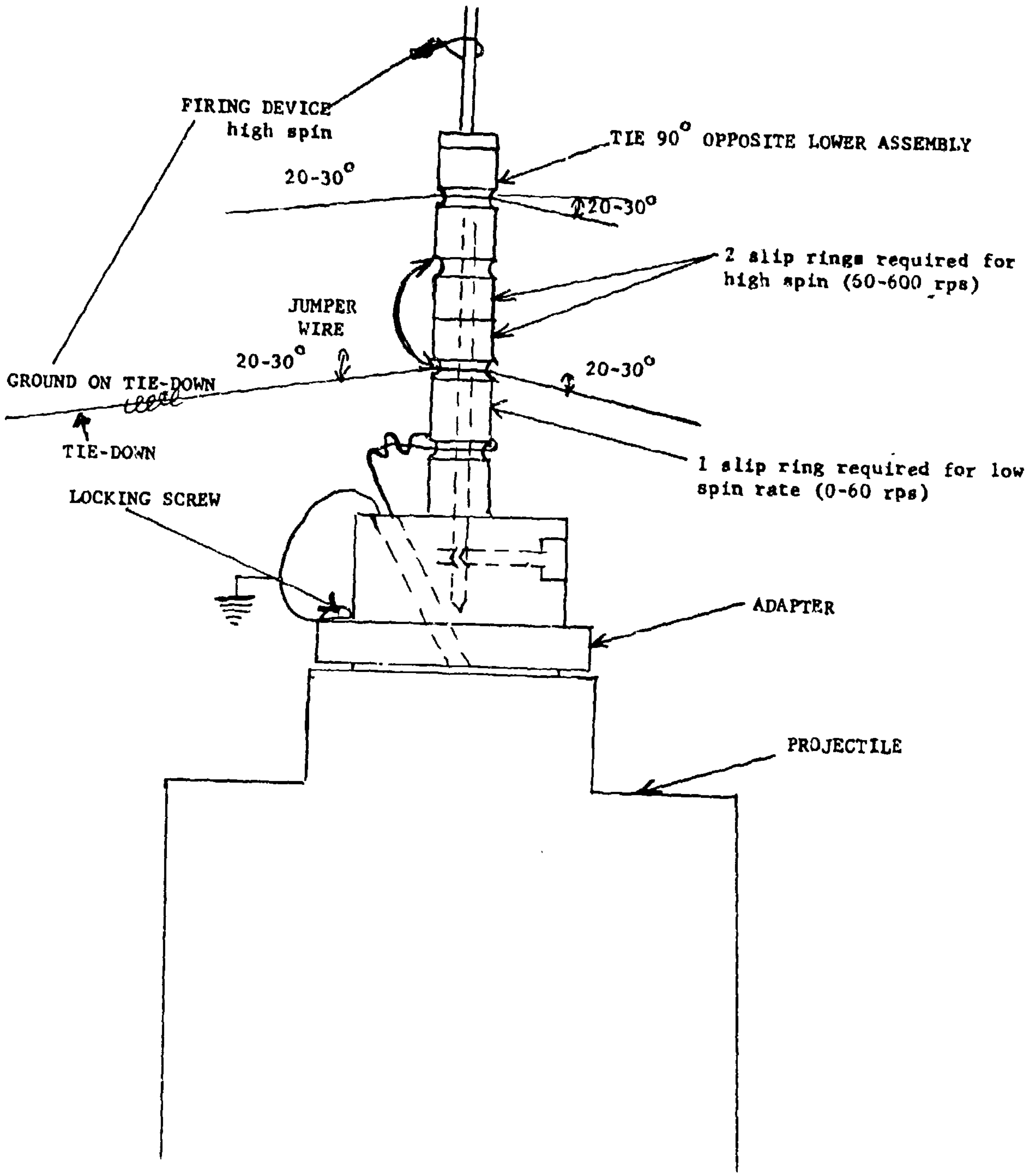

Figure 5. Example of hookup of slip ring(s) and spin adaptors to M456 projectile body.

4.2 Dynamic Tests. Although static testing of HEAT warhead designs is useful for many purposes, no evaluation of a warhead can be considered complete unless dynamic firings are conducted against armor targets set at obliquities of 0°, 60°, and others as required.

Some of the factors that must be considered in planning a dynamic evaluation of HEAT warheads are: a) the velocity of the round contributes to the velocity of the jet that penetrates the armor; thus, realistic projectile velocities must be used; b) some fuzes will tend to function too slowly to overcome the effects of high obliquity or unusual impact surfaces, thereby reducing the penetration ability of the round; c) the penetrating ability of some rounds will be sharply reduced by the standoff provided by spaced armor, appliques, roadwheels, external stowage on the vehicle, etc., and d) penetrating ability can be affected by spin rate and yaw. Dynamic tests of HEAT warheads should consider all the targets necessary to evaluate the influence of these factors. The resistance of armor to penetration by HEAT projectiles is covered in TOP 2-2-710.[2]

a. Method. Conduct dynamic tests of HEAT warheads against the required armor targets under controlled conditions of target obliquity and standoff distance. Position target armor plate of a size compatible with system accuracy and projected area, at obliquities specified. If penetration depth is to be determined, the basic armor target must be thick enough (in layers if necessary) to contain the penetrating jet. To achieve large standoff distances, function the fuze on a bursting target of light plywood in front of the target armor plate. The bursting target should only be as heavy as will reliably function the fuze. Record fuze functioning and attitude of the test item by high speed photography or flash radiography (TOP 4-2-825).[3] Obtain behind-the-plate fragmentation data, if required, by collecting the exiting fragments in appropriately located stacks of recovery media (wallboard, Celotex, etc., interspaced with aluminum foil).

Unless otherwise specified, conduct tests against conventional armor by firing 10 rounds at the target for each test condition, i.e., for each combination of standoff distance, target configuration, and obliquity specified. Standoff distances will be selected in such a way as to provide correlation with dynamic standoff-versus-penetration data generated during static tests (see Table 1). Impacts are considered fair hits when there is one projectile diameter or more between the edges of the lips of the front side jet-produced holes (fig. 6), as well as from the edge of the plate or the lifting hole in the plate.

When required, repeat the test procedure with the test items conditioned to 63° C and -45° C, or as specified in the test directive. When specified, measure penetration hole profiles in the armor plate, using the techniques described in Appendix B.

b. Data Required. Record the following for each round launched:

(1) Test item temperature and ambient temperature
(2) Target configuration and thickness of every armor plate employed and spacing between plates
(3) Hardness of armor plate
(4) Target obliquity
(5) Test item standoff distance in charge diameters
(6) Distance from test weapon to test target in meters
(7) Type and distance of bursting target

(8) Muzzle velocity
(9) Total number of fragments collected in each witness sheet
Fragment distribution
(10) Description of test setup
(11) Penetration in cm
(12) Penetration (hole) profile and volume (if requested)

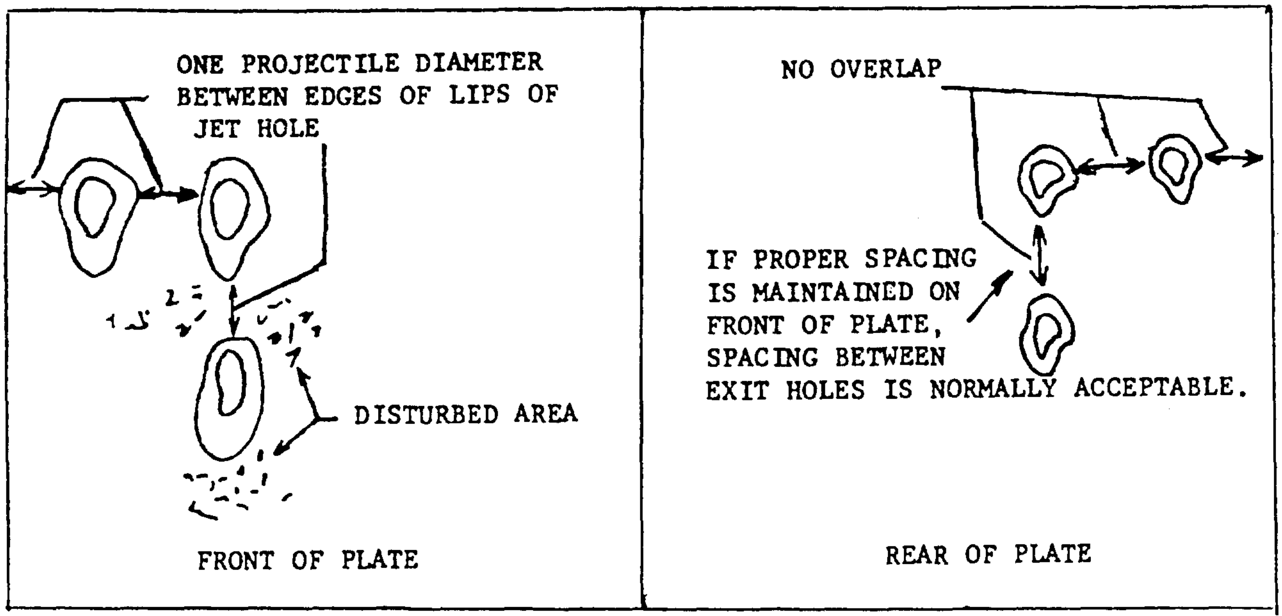

Figure 6. Fair hit criteria.

5. DATA REDUCTION AND PRESENTATION. Tabulate all data, compute mean and standard deviation of depths of penetration for each test condition, and when applicable, plot mean plate penetration depth versus warhead standoff distance (fig. 7) for each test. Depth of penetration versus test temperature should also be plotted. For static spin tests, an additional plot showing penetration versus spin rate (fig. 8) may be required. When depth of penetration is compared against a standard or against another warhead design, make a statistical comparison using the Student's t-test for equality of means or Snedecor's F-test for equality of variances (using a significance level of 0.10). It is assumed that depths of penetration are normally distributed. Data presentations should include appropriate photographs, radiographs, sketches, graphs, or other pictorial or graphic presentations that will support test results or conclusions.

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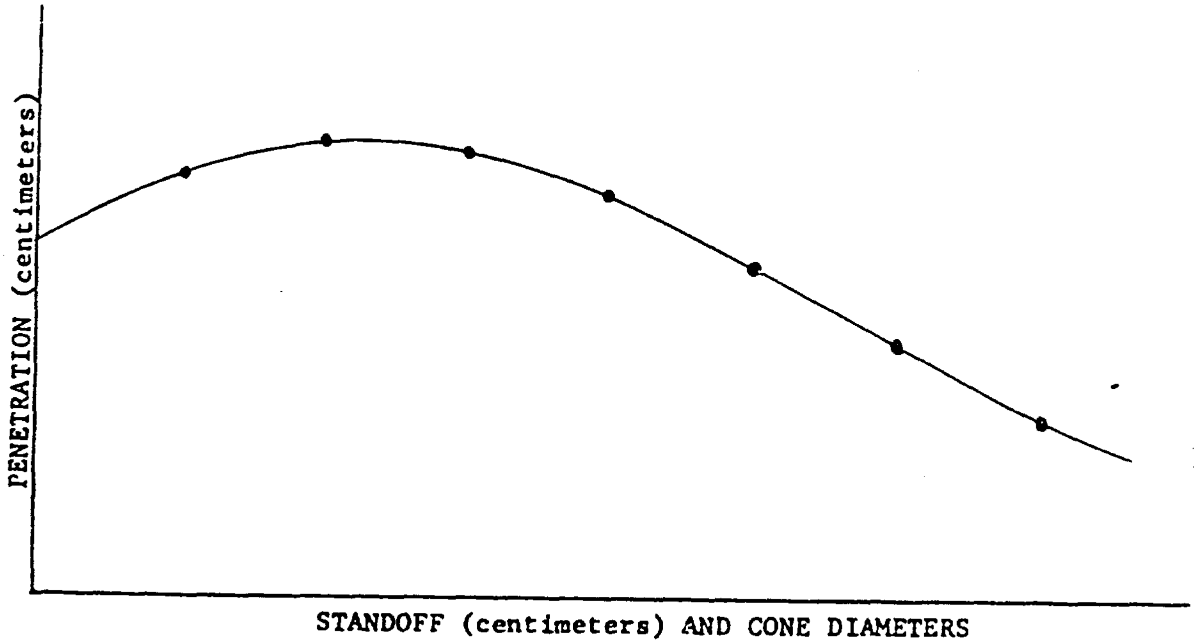

Figure 7. Plot of penetration versus standoff.

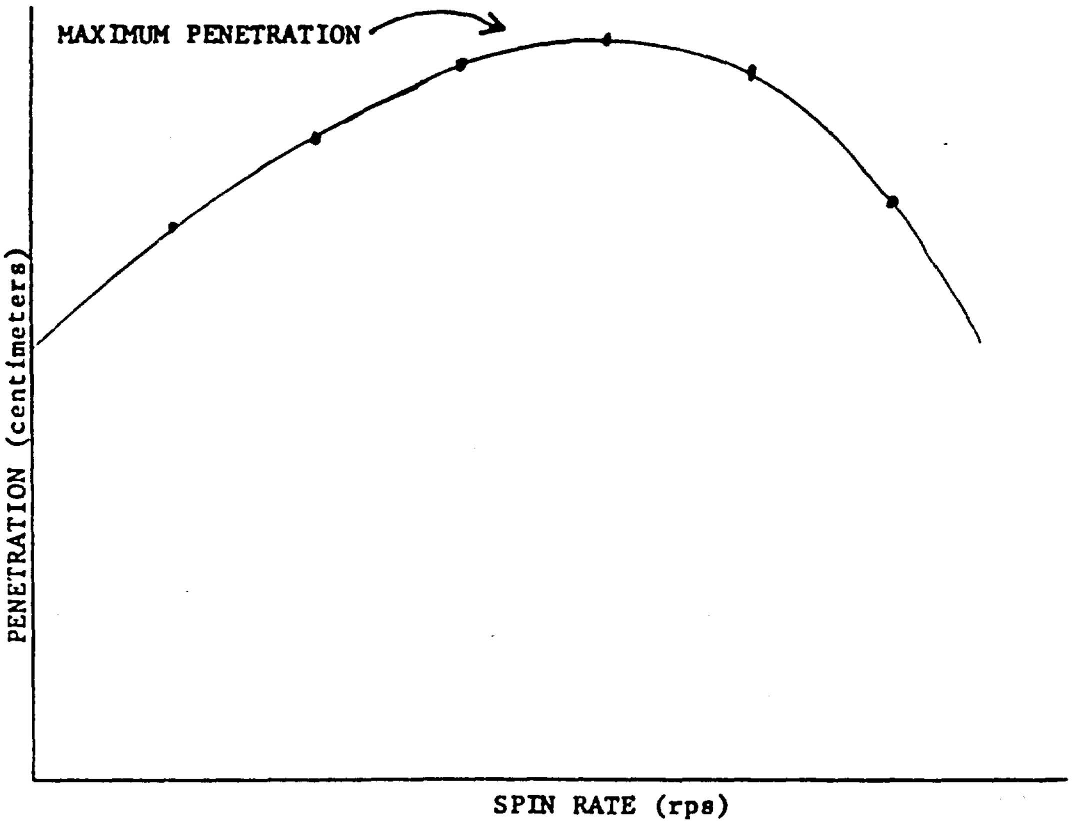

Figure 8. Plot of penetration versus spin rate for a spin-compensated cone.

APPENDIX A
TYPICAL HEAT WARHEAD

A typical HEAT warhead, also called a shaped charge warhead, is illustrated in Figure A-1. The most significant aspect of this type of warhead lies in the cavity and its liner which is usually conical and manufactured of copper. Detonation of the warhead explosive filler forces the inner surface of the liner into a small-diameter fluid stream that moves into the target plate at extremely high speed, often 8000 m/s or more. Thus, a warhead of nominal weight impacting the target at relatively low velocity can effectively penetrate heavy armor targets. A point-initiating base-detonating (PIBD) fuze or a base-detonating fuze is used to function the warhead at the required standoff distance for penetration. The latest effort in HEAT round fuzing entails a point- or shoulder-initiating base-detonating fuze which is often referred to as a "full frontal area impact switch" (FFAIS). The charge diameter is a basic dimension of the HEAT warhead, and is used in measuring standoff distances to evaluate the capability of the warhead design.

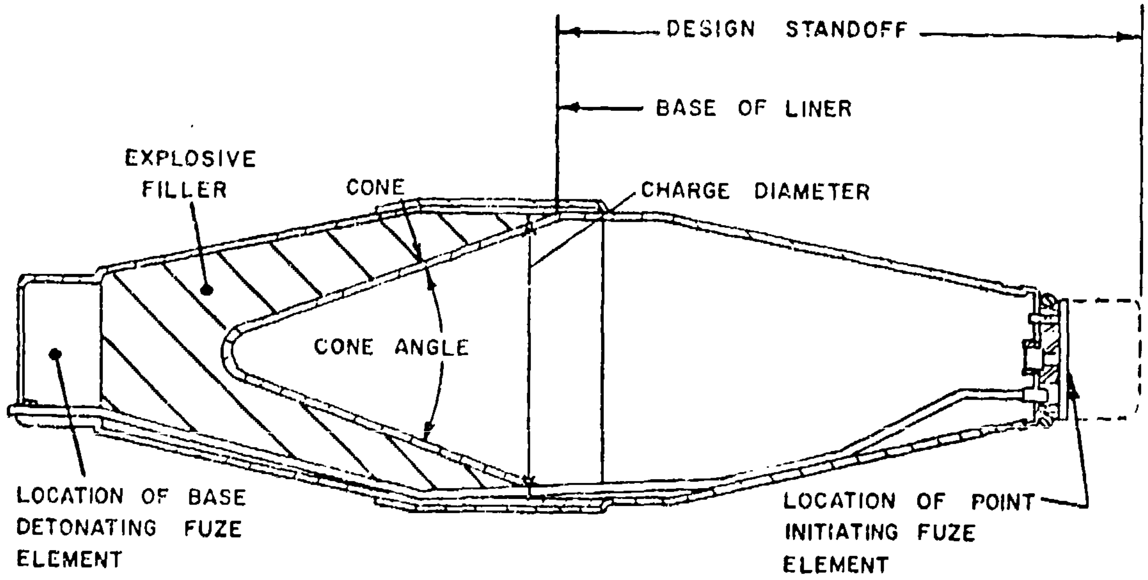

Figure A-1. Typical HEAT warhead showing location of major components.

APPENDIX B
TECHNIQUES OF PENETRATION MEASUREMENTS

Two items pertaining to the hole made by a shaped charge jet are important: 1) the depth of the hole, and 2) the volume and/or profile of the hole. The first must be known in every case because it tells how much armor can be penetrated; the second is determined in selected cases because hole diameter and volume indicate the spread of fragments that will result when the jet perforates an armor wall.

The profile, depth, and volume can be determined by radiographic means. The volume can also be determined by the flame-cutting method or by ruler measurements. The various methods of measuring hole size are described below:

1. Probe Measurement. Before a probe is inserted, it is necessary to drill into the hole to permit passage of the probe. The drill (portable is satisfactory) will penetrate the material (usually copper) which is from the cone of the warhead, that is blocking the hole. The resistance of the hard armor at the bottom of the hole will make it apparent when the drill bit reaches bottom. The depth of penetration is measured along the axis of the penetration, rather than normal to the plate.

2. Radiographic Measurement. The use of radiographic equipment (TOP 3-2-807) to determine the hole profile data requires that a square of the plate containing the hole be burned/sawed from the individual plate (sawing produces a smoother cut, but burning is faster and cheaper). The maximum thickness of the plate remaining around the hole should be less than 5 cm (2.5 cm preferred), depending on the capability of the X-ray equipment to be used. Radiograph the plate and hole (side view), and rotate the samples 90° and radiograph again. Then obtian hole diameters at specific intervals along the penetration axis by directly measuring the radiographs.

This method permits a thorough examination of the hole profile, including any portions that have been refilled with residue from the warhead liner (the difference in two types of metal, i.e., of the target and liner, are readily discernible).

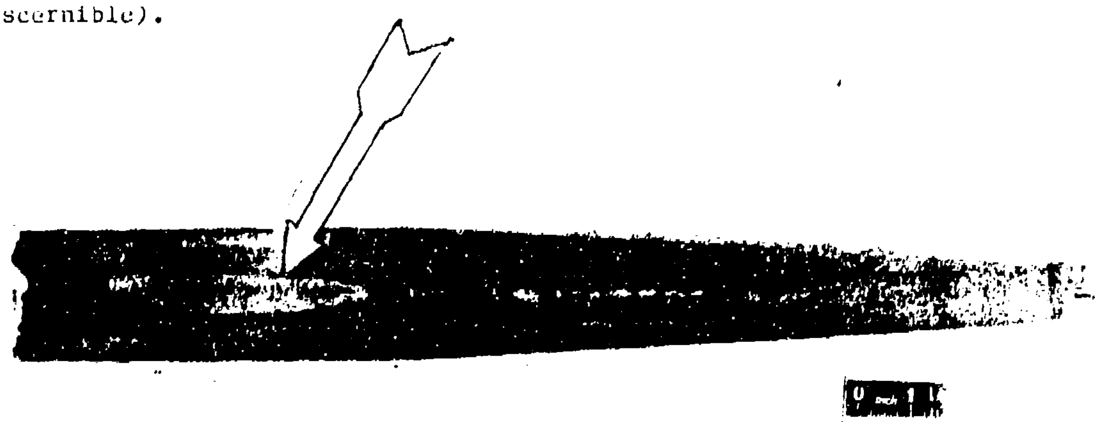

Figure B-1. Photograph of a sectioned armor target after partial penetration by a HEAD warhead.

Jet material has plugged the bottom of the hole, and the slug (arrow) is wedged into the hole near the penetration entrance.

3. Water Measurement. To determine volume, the technique used is selected according to the test requirements. Measurement techniques must be described, and error tolerance must be indicated. One procedure known as the "electrolytic water volume" is described below.

The plate with the penetration hole to be measured is supported horizontally (level) so that the exit hole in the plate, which is placed on the bottom, is accessible. Seal the exit hole by placing a ring of plasticine around the perforation and squeezing it into a watertight seal with a small steel plate. Use an electrical probe and ohmmeter to determine linear measurement along the penetration hole axis. Raise the probe a specific increment from the surface of the sealing plate, and a measured quantity of water will be introduced into the cavity from a burette until an electrical circuit is completed by the water rising to the level of the probe tip. Then raise the probe tip another controlled increment and repeat the process until completion. Determine the hole profile by calculating the average diameter based on the volume of water introduced in each controlled increment of the hole.

Take care that the volumes created by the formation of raised edges around the jet entrance and exit areas are not added to the volume of material displaced between the original flat surfaces of the plate.

Generally, one or two plates in each stack per round will have an obstruction, i.e., core residue or incomplete penetration as shown in Figure B-1. The water-measurement technique cannot be used on these plates due to leakage at the laminations. Therefore, the radiographic technique is used.

4. Flame Cutting. When working with laminated steel packets, personnel may flame-cut the jet hole out of the individual plates (cut out to the undeformed plate), and weigh the piece(s). Then compute the weight difference based on the weight of the original plate thickness.

5. Ruler Measurement. When using laminated steel packets, personnel can also determine the volume and profile of the hole by disassembling the packet and measuring the diameter of the hole, front and rear, of each plate, and tabulating the total volume.

APPENDIX C
REFERENCES

1. Test Operations Procedure (TOP) 3-2-807, Nondestructive Testing of Materials, 11 September 1972.

2. TOP 2-2-710, Ballistic Tests of Armor Materials, 6 April 1977.

3. TOP 4-2-825, Flash Radiography in Ballistic Testing, 8 June 1978.